



TITLE:

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CITATION:

Shigehara, Nobuo ...[et al]. Similarities of the Molar Size in Various Squirrel Monkeys (Saimiri, Ceboidea). Kyoto University overseas research reports of new world monkeys 1990, 7: 25-31

ISSUE DATE:

1990

URL:

<http://hdl.handle.net/2433/199641>

RIGHT:

Kyoto University Overseas Research
 Reports of New World Monkeys (1990) 7: 25–31
 Kyoto University Primate Research Institute

Similarities of the Molar Size in Various Squirrel Monkeys (*Saimiri*, Ceboidea)

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INTRODUCTION

Squirrel monkeys are commonly used in the laboratory as experimental animals, but the taxonomy of this genus *Saimiri* has been confused (COOPER, 1968). Traditionally, all squirrel monkeys have been placed in a single species, *Saimiri sciureus*. CABRERA (1957) stated that the many species should be reduced to two at most: *Saimiri sciureus* which lives in South America and *Saimiri oerstedii* which lives in Central America (NAPIER & NAPIER, 1967; SZALGY & DELSON, 1979). However, HILL (1960) recognized the following five species, *Saimiri sciureus*, *S. oerstedii*, *S. usta*, *S. madeirae* and *S. boliviensis*. HERSHKOVITZ (1984) recognized many allopatric species. On the basis of the division of the squirrel monkeys, MCLEAN (1964) recognized nine groups in two major division, Roman type and Gothic type.

We follow the classification proposed by HERSHKOVITZ, and measured molar tooth size since little information is available on the tooth size of the squirrel monkeys, except for that reported by ORLOSKY (1973) and SWINDLER (1976).

MATERIALS AND METHODS

Table 1 shows the materials used in this study. These 173 squirrel monkeys (8 groups) were kept in the Field Museum of Natural History in Chicago and the American Museum of Natural

Table 1. Materials used in this study

	Male	Female
<i>Saimiri sciureus sciureus</i>	21	12
<i>Saimiri sciureus cassiquiarensis</i>	2	4
<i>Saimiri sciureus macrodon</i>	34	29
<i>Saimiri sciureus albigena</i>	15	2
<i>Saimiri ustus</i>	5	3
<i>Saimiri oerstedii</i>	4	3
<i>Saimiri boliviensis boliviensis</i>	9	9
<i>Saimiri oliviensis peruviansis</i>	14	7
Total	104	69

Tabel 2. Molar size in various squirrel monkeys (male) (mm)

		<i>S. ustus</i>			<i>S. peruviansis</i>			<i>S. s. cassigua.</i>			<i>S. s. albigena</i>			<i>S. s. macrodon</i>			<i>S. oerstedii</i>			<i>S. boliviensis</i>			<i>S. s. sciureus</i>		
		No.	♂	Ave.	SD	No.	♂	Ave.	SD	No.	♂	Ave.	SD	No.	♂	Ave.	SD	No.	♂	Ave.	SD	No.	♂	Ave.	SD
Upper jaw																									
M1	m-d	5	2.59	0.09	13	2.61	0.11	2	2.57	0.04	13	2.80	0.09	30	2.77	0.11	3	2.57	0.06	7	2.59	0.07	21	2.69	0.10
	b-l	5	4.02	0.14	13	4.01	0.11	2	4.03	0.13	13	4.09	0.12	30	4.02	0.14	3	3.70	0.03	7	4.10	0.09	21	4.08	0.16
M2	m-d	5	2.29	0.15	13	2.31	0.11	2	2.26	0.10	13	2.35	0.09	30	2.37	0.11	3	2.20	0.12	7	2.31	0.07	21	2.24	0.13
	b-l	5	3.69	0.25	13	3.73	0.16	2	3.55	0.01	13	3.72	0.12	30	3.65	0.15	3	3.47	0.10	7	3.82	0.17	21	3.70	0.17
M-3	m-d	3	1.54	0.05	10	1.36	0.13	2	1.52	0.08	13	1.64	0.10	30	1.57	0.13	2	1.48	0.03	7	1.35	0.10	21	1.61	0.12
	b-l	3	2.75	0.30	10	2.41	0.20	2	2.40	0.01	13	2.57	0.18	30	2.62	0.29	2	2.28	0.06	7	2.47	0.16	21	2.63	0.20
Lower jaw																									
M1	m-d	5	2.69	0.17	13	2.72	0.14	2	2.83	0.01	13	2.91	0.08	30	2.80	0.12	3	2.68	0.08	7	2.67	0.09	21	2.85	0.13
	m (b-l)	5	2.77	0.09	13	2.78	0.14	2	2.62	0.08	13	2.91	0.12	30	2.88	0.14	3	2.57	0.03	7	2.78	0.10	21	2.81	0.13
	d(b-l)	5	2.71	0.11	13	2.68	0.15	2	2.65	0.13	13	2.77	0.11	30	2.74	0.13	3	2.43	0.04	7	2.68	0.12	21	2.66	0.20
M2	m-d	5	2.49	0.09	13	2.56	0.16	2	2.56	0.05	13	2.65	0.12	30	2.49	0.15	3	2.52	0.12	7	2.52	0.08	21	2.65	0.11
	m(b-l)	5	2.62	0.10	13	2.54	0.10	2	2.50	0.08	13	2.74	0.14	30	2.68	0.13	3	2.42	0.03	7	2.54	0.11	21	2.64	0.15
	d(b-l)	5	2.37	0.08	13	2.36	0.13	2	2.30	0.02	13	2.38	0.14	30	2.39	0.15	3	2.16	0.00	7	2.39	0.09	21	2.41	0.15
M3	m-d	5	2.14	0.13	12	2.12	0.13	2	2.24	0.11	12	2.17	0.12	27	2.09	0.15	3	2.12	0.05	7	2.09	0.13	21	2.24	0.10
	m(b-l)	5	2.00	0.13	12	1.97	0.07	2	1.83	0.02	12	2.11	0.09	27	2.06	0.16	3	1.97	0.08	7	1.98	0.12	20	2.06	0.16
	d(b-l)	5	1.69	0.09	12	1.63	0.08	2	1.60	0.01	12	1.72	0.11	27	1.69	0.15	2	1.49	0.01	7	1.64	0.10	20	1.77	0.13

Table 3. Molar size in various squirrel monkeys (female) (mm)

		<i>S. ustus</i>			<i>S. peruviansis</i>			<i>S. s. cassiciua.</i>			<i>S. s. albigena</i>			<i>S. s. macrodon</i>			<i>S. oerstedii</i>			<i>S. boliviensis</i>			<i>S. s. sciureus</i>		
		No.	♀	Ave.	SD	No.	♀	Ave.	SD	No.	♀	Ave.	SD	No.	♀	Ave.	SD	No.	♀	Ave.	SD	No.	♀	Ave.	SD
Upper jaw																									
M1	m-d	2	2.72	0.02	6	2.60	0.16	3	2.64	0.03	3	2.83	0.11	21	2.76	0.11	3	2.59	0.03	8	2.60	0.08	12	2.68	0.13
	b-l	2	4.15	0.06	6	3.97	0.19	3	3.95	0.07	3	4.11	0.08	21	4.01	0.12	3	3.76	0.20	8	4.03	0.21	12	4.07	0.14
M2	m-d	2	2.41	0.07	6	2.30	0.07	3	2.30	0.13	3	2.46	0.05	20	2.40	0.17	3	2.39	0.12	8	2.23	0.09	12	2.21	0.10
	b-l	2	3.58	0.27	6	3.68	0.17	3	3.62	0.05	3	3.56	0.33	20	3.64	0.19	3	3.46	0.09	8	3.59	0.14	12	3.52	0.42
M3	m-d	2	1.44	0.01	6	1.44	0.12	2	1.57	0.09	2	1.66	0.04	21	1.56	0.09	2	1.56	0.08	8	1.27	0.12	11	1.64	0.13
	b-l	2	2.47	0.04	6	2.51	0.18	2	2.54	0.37	2	2.47	0.15	21	2.55	0.23	2	2.32	0.29	8	2.24	0.18	12	2.65	0.18
Lower jaw																									
M1	m-d	2	2.67	0.04	7	2.76	0.10	3	2.76	0.06	3	2.97	0.19	21	2.85	0.16	3	2.72	0.11	8	2.64	0.09	12	2.81	0.12
	m(b-l)	2	2.88	0.06	7	2.67	0.12	3	2.76	0.02	3	2.98	0.16	21	2.84	0.13	2	2.52	0.06	8	2.71	0.12	12	2.75	0.13
	d(b-l)	2	2.72	0.10	7	2.64	0.12	3	2.70	0.04	3	2.75	0.15	21	2.72	0.10	3	2.51	0.07	8	2.61	0.13	12	2.63	0.14
M2	m-d	2	2.49	0.07	7	2.55	0.08	3	2.61	0.17	3	2.64	0.15	21	2.52	0.12	3	2.52	0.05	8	2.50	0.13	12	2.63	0.11
	m(b-l)	2	2.65	0.14	7	2.46	0.14	3	2.50	0.05	3	2.80	0.12	21	2.68	0.13	3	2.41	0.11	8	2.44	0.13	12	2.61	0.13
	d(b-l)	1	2.54	—	7	2.30	0.09	3	2.33	0.13	3	2.42	0.14	21	2.41	0.13	3	2.16	0.14	8	2.27	0.09	12	2.33	0.10
M3	m-d	2	2.14	0.05	7	2.22	0.15	3	2.09	0.07	3	2.25	0.07	21	2.08	0.19	2	1.98	0.16	8	2.02	0.08	12	2.29	0.33
	m(b-l)	2	2.05	0.08	7	1.95	0.13	3	1.94	0.15	3	2.13	0.14	21	2.03	0.13	2	1.93	0.04	8	1.95	0.16	12	2.07	0.16
	d(b-l)	2	1.72	0.01	7	1.66	0.13	3	1.77	0.09	3	1.66	0.06	20	1.68	0.12	2	1.49	0.11	7	1.61	0.09	12	1.83	0.38

History in New York. The medio-distal and bucco-lingual crown diameters were measured. Tables 2 and 3 give the numbers and the means for each tooth in each group.

We used a digital caliper for taking measurements. Teeth on the right side were measured. When teeth were missing, their antimeres were used.

We used the Q-mode correlation coefficients SNEATH and SOKAL (1973) recommended as the best method for obtaining the biological distance. Some other statistical procedures were also used to make the affinities among the squirrel monkeys clearer.

RESULTS AND DISCUSSION

a) Sexual Difference

The difference in molar tooth size between males and females is not as clear as that in anterior teeth size (canine, mandibular canine and premolar) reported by ORLOSKY (1973) and SWINDLER (1976). Significant differences ($P < 0.05$) were observed only, in three measurements of *S. boliviensis boliviensis* within four squirrel monkeys by Student's T-test (Table 4).

b) Principal Component Analysis

Characteristics in the medio-distal and bucco-lingual crown diameter in each group were analyzed by applying a Principal Component Analysis (PCA).

First, a correlation matrix was obtained from the pooled data for the eight groups, and a PCA was applied to this matrix. As a result of this procedure a matrix of rotated factor loadings was obtained (Table 5). In this case, all the molar teeth are explained by the first five components which represent 73 percent of the total variance.

The first component shows a high correlation with the bucco-lingual diameter of the lower first and second molar, the second with the size of the upper and lower third molar, the third with the

Table 4. Sexual difference of the molar size in the squirrel monkeys

●: significant difference ($P < 0.01$); ○: significant difference ($P < 0.05$);

×: no significant difference

		<i>boliviensis</i>	<i>sciureus</i>	<i>macrodon</i>	<i>peruviensis</i>
Upper jaw					
M1	m-d	×	×	×	×
	b-l	×	×	×	×
M2	m-d	×	×	×	×
	b-l	○	×	×	×
M3	m-d	×	×	×	×
	b-l	○	×	×	×
Lower jaw					
M1	m-d	×	×	×	×
	m(b-l)	×	×	×	×
	d(b-l)	×	×	×	×
M2	m-d	×	×	×	×
	m(b-l)	×	×	×	×
	d(b-l)	○	×	×	×
M3	m-b	×	×	×	×
	m(b-l)	×	×	×	×
	d(b-l)	×	×	×	×
Max. cra. l.		○	●	●	○

Table 5. Varimax criterion of the molar size in the squirrel monkeys by factor analysis

		a(1)	a(2)	a(3)	a(4)	a(5)
Upper jaw						
M1	m-d	0.2267	0.2477	0.8269	0.0665	-0.0501
	b-l	0.2471	0.2419	0.3777	0.5376	0.1555
M2	m-d	0.0984	0.1965	0.6361	0.4851	0.0429
	b-l	0.1447	0.0285	-0.0077	0.8939	0.0210
M3	m-d	0.0929	0.7435	0.3458	-0.0048	0.2276
	b-l	0.0899	0.6293	0.3590	0.4191	-0.0059
Lower jaw						
M1	m-d	0.3224	0.0265	0.6727	-0.0544	0.4196
	m(b-l)	0.7820	0.1182	0.2927	0.2888	0.1799
	d(b-l)	0.7752	0.0535	0.1301	-0.0249	-0.0506
M2	m-d	0.0703	0.0896	0.1997	0.0874	0.8850
	m(b-l)	0.6951	0.4021	0.3425	0.2269	0.1531
	d(b-l)	0.6797	0.4374	-0.0178	0.3683	0.0682
M3	m-d	0.0498	0.5619	-0.1879	0.0374	0.6474
	m(b-l)	0.4919	0.5274	0.1600	0.0696	0.1207
	d(b-l)	0.2941	0.7348	0.0621	0.1038	0.0694

medio-distal diameter of the upper first and second molar and the lower first molar, the fourth with bucco-lingual diameter of upper second molar, and the fifth with the medio-distal diameter of the lower second and the third molar.

The Polygon Bas method was applied to the standardized score of each group. Using five scores, characteristics in the shape component of molars can be expressed by pentagons, as shown in Fig. 1. The axes of the pentagons connecting the center point and each vertical angle represent each component, in which the innermost point represents -1 standard deviation of the scores, and the outermost point +1 standard deviation, so that the middle point of the axes corresponds to the grand mean of the principal component scores. Thus, the mean values of the scores in each population are expressed in standard deviation units, and the dotted areas represent the characteristics of populations as expressed by the principal component scores.

The pentagon pattern of *S. boliviensis boliviensis* and *S. b. peruviansis* are similar except for PC-4. *Saimiri ustus* is similar pattern to these Roman type squirrel monkeys. *Saimiri oerstedii* has the smallest tooth size of 9 groups. *S. sciureus macrodon* is of medium overall size in spite of his nomenclature. *S. s. albigena* has similar pentagon pattern with *S. s. macrodon*. *S. s. cassiquarensis* and *S. oerstedii* have a small PC-1 which relates to the bucco-lingual diameters of the lower first and second molar.

c) Cluster Analysis

The eight groups are classified into two major clusters (Fig. 2). The first cluster includes the Roman type squirrel monkey (*S. boliviensis boliviensis* and *S. b. peruviansis*) and *Saimiri ustus*. The second cluster includes Gothic type squirrel monkeys, *S. sciureus macrodon*, *S. s. cassiquarensis*, *S. oerstedii*, *S. s. sciureus* and *S. s. albigena*. Within the first major cluster, the Roman type makes one cluster. They have very similar molar size, as is seen in the pentagon figures. This cluster pattern is parallel to the systematics reported by MITTERMEIER, RYLANDS and COIMBRA-FILHO (1988).

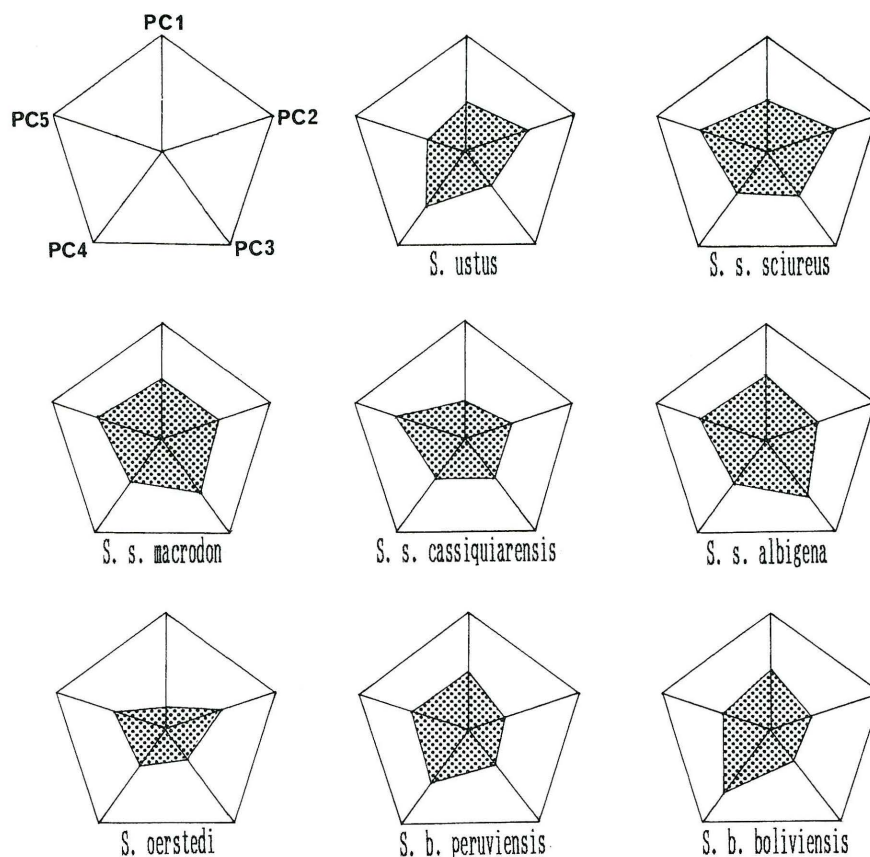


Fig. 1. Pentagon patterns based on mean Principal Component Scores.

Next, we selected next five groups with rather large sample size; *S. sciureus sciureus*, *S. s. macrodon*, *S. s. albigena*, *S. boliviensis boliviensis* and *S. b. peruviansis*. This cluster also matches the classification by MITTERMEIER et al. (1988).

d) Third Molar Reduction

We calculated the rate of the third molar size to the first molar size and applied a PCA to know the degree of the third molar reduction in each group (Tables 6, 7).

In this PCA, *S. boliviensis peruviansis* and *S. b. boliviensis* show a low average score (*S.p.*; -1.098 , *S.b.*; -0.925) compared with other squirrel groups. This means strong third molar reduction. On the contrary, *S. sciureus sciureus* and *S. oerstedii* show higher values (1.048 and 0.930 respectively). This means a weak third molar reduction.

The rate of the third molar reduction varied among the various squirrel monkey groups. The Roman type squirrel monkeys showed a higher reduction rate than the Gothic type squirrel monkeys.

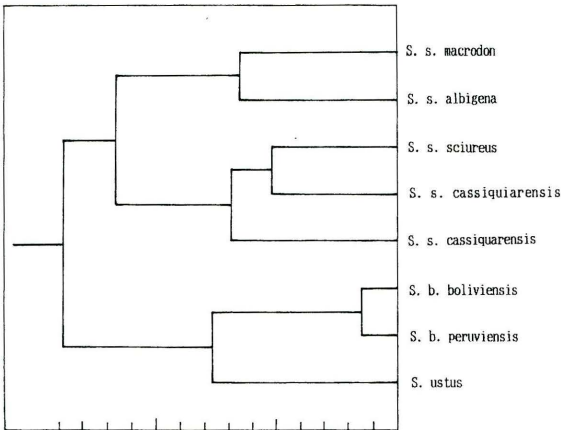


Fig. 2. Dendrogram of the eight groups of the squirrel monkeys based on the molar size measurements.

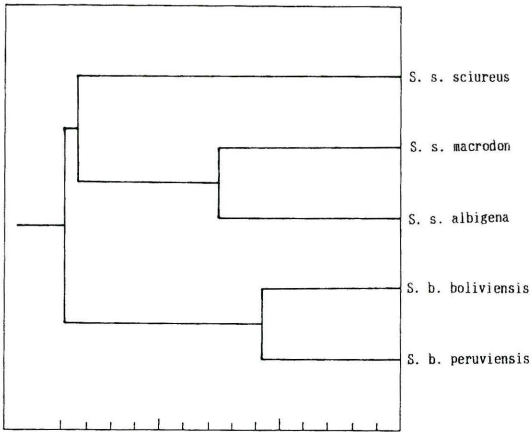


Fig. 3. Dendrogram of the five groups of the squirrel monkeys with large sample size based on the molar size measurements.

Table 6. Eigenvalues and eigenvectors of the correlation matrix in the squirrel monkeys

	1	2	3	4	5
Upper M3/M1					
m-d:X(1)	0.55893	-0.10145	-0.10557	0.07626	-0.81261
b-l:X(2)	0.40687	-0.72924	0.00157	0.37172	0.40558
Lower M3/M1					
m-d:X(3)	0.40124	0.65610	0.08171	0.58732	0.23857
m(b-l):X(4)	0.43683	0.15732	-0.64893	-0.51266	0.31702
d(b-l):X(5)	0.41260	0.05195	0.74904	-0.49825	0.13324
Eigen	1.97170	0.90419	0.83321	0.74405	0.54686
Proportion	0.39434	0.18084	0.16664	0.14881	0.10937
Cum. prop.	0.39434	0.57518	0.74182	0.89063	1.00000

Table 7 Average scores of the M3/M1 PCA in each group

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
<i>S. ustus</i>	0.421	-0.622	0.439	0.698	-0.161
<i>S. oerstedii</i>	0.930	0.987	-0.890	0.320	0.134
<i>S. s. sciur.</i>	1.048	0.141	0.493	-0.105	-0.183
<i>S. s. cassi.</i>	-0.385	0.662	0.017	0.461	-0.685
<i>S. s. alvig.</i>	-0.010	-0.060	-0.259	-0.159	0.151
<i>S. s. macrod.</i>	-0.041	-0.412	-0.206	-0.135	0.151
<i>S. b. peruv.</i>	-1.098	0.602	-0.073	0.264	0.373
<i>S. b. boliv.</i>	-0.925	0.697	0.135	0.150	0.631

ACKNOWLEDGEMENT

This research would not have been possible without the kind cooperation received from the curatorial and research staff of the Field Museum of Natural History and of the American Museum of Natural History where the specimens employed in this study are deposited. We also wish to thank Dr. P. HERSHKOVITZ for his kind help in the Field Museum and Dr. N. HANIHARA for his help in statistical analysis.

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